LED-BASED MICRO DISPLAY FOR AN INTRAOCULAR VISION AID (IOVA)

D. Püttjer, F. Prämaßing, R. Buß, D. Jäger
ZHO-Department of Optoelectronics, Gerhard-Mercator-University, Duisburg, Germany

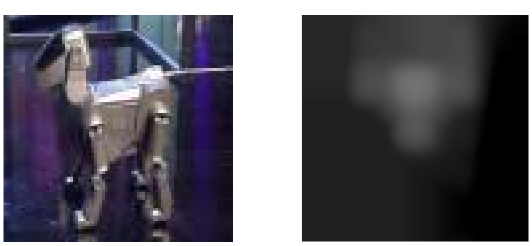
Abstract-**In this Paper a micro display for an intraocular vision aid (IOVA) projecting an image of the environment onto the retina is presented. The display comprises an image of an array made out of single LED pixels. It is connected to a CMOS driver circuit using flip-chip technique. Since micro lenses have to be integrated into the substrate material for proper image projection onto the retina the generated light has to pass the substrate. Thus, only semiconductors with adequate large band gap energies are suitable. This paper discusses the principle of GaAsP material systems for an LED-based micro display applied to an implantable vision aid.**
***Keywords* – *i*ntraocular vision aid, IOVA, GaAsP, LED array, micro display**

I. Introduction

The objective of IOVA is providing artificial vision to people suffering from blindness due to opaque cornea [1], [2]. By applying IOVA to blind people it is supposed to restore some primitive kind of vision, e.g. giving them back again their orientation in an unknown environment. An example of the expected deterioration in vision is shown in fig. 1.

II. Methodology

In order to bridge the opaque cornea the following concept has been developed. A high dynamic range CMOS camera placed outside of the eye generates a digital black and white image which is converted by a digital signal processing unit (DSP) into a serial bit-stream with a data rate of approximately 1 Mbits per second [3]. This bit-stream in conjunction with the energy is transmitted wirelessly to an implantable micro display encapsulated in an intraocular lens [4], [5]. It consists of a receiver for power supply, data and clock recovery and a miniature LED array flip-chip bonded to a silicon CMOS driver circuit. Fig. 2 shows a sketch of the system concept described above. Details of the signal transmission technique can be found in [4].



Sight of people having unlimited vision.

Sight of blind people having a blurred cornea.

Fig. 1. Comparison between normal and harmed vision.

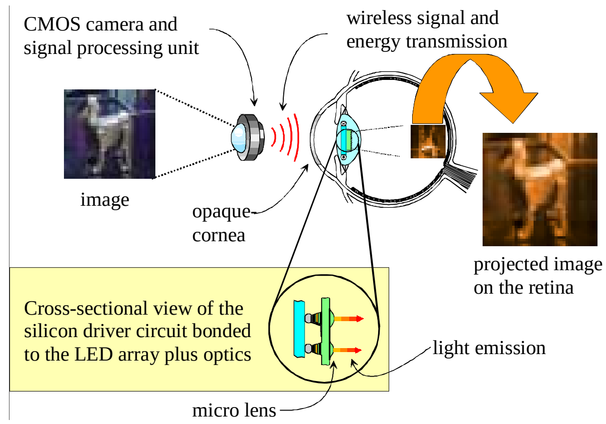


Fig. 2. System concept of the intraocular vision aid.

A. LED array

For the selection of the wavelength emitted by the LED array the standard observer function V(λ) defined by the Commision Internationale d' Eclaire (CIE) has been taken into consideration, confirm fig. 3. The semiconductor materials suitable for the LED array have to meet the following requirements:

- Due to the maximum value of V(λ) the emitted wavelength λ has to be in wavelength region between 500 nm and 600 nm.
- For this wavelength region the substrate of the required material system has to be transparent.

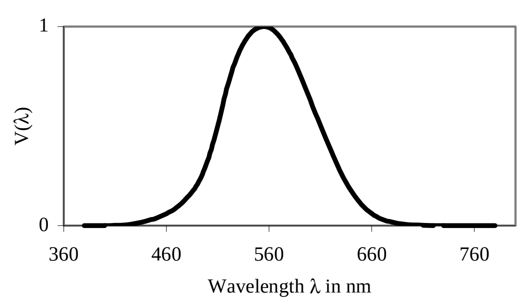


Fig. 3. The photopic standard observer function V(λ) defined by the CIE.

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Led-Based Micro Display For An Intraocular Vision Aid (IOVA)	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) ZHO-Department of Optoelectronics Gerhard-Mercator University Duisburg, Germany	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited	
Supplementary Notes Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom., The original document contains color images.	
Abstract	
Subject Terms	
Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU
Number of Pages 4	

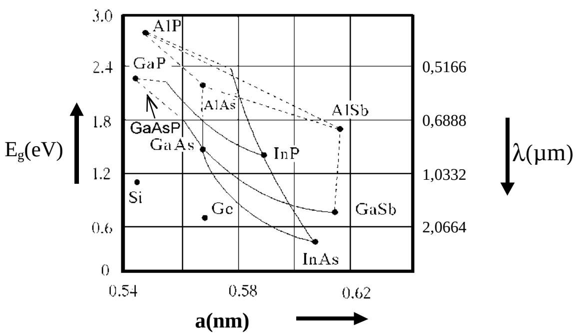


Fig. 4. Lattice constant a versus bandgap energy E_g and wavelength λ.

Considering the restriction mentioned above the material system GaAsP based on GaP substrate as a material with a sufficiently high energy gap was chosen. In this context fig. 4 shows the bandgap energy versus lattice constant for various semiconductors as an additional important technological property. To avoid critical tensions of the crystal several layers of n-doped GaAsP with increasing arsine concentration were epitactically grown on n-doped GaP substrate. In the active zone nitrogen was included to improve the efficiency [6], [7]. The layer system of the LED closes up with p-doped GaAsP. One design of the above described LED structure is shown in fig. 5.

B. Bonding process

The LED array is connected to the silicon driver circuit by means of flip-chip technology. Gold bumps are bonded onto the Si-driver circuit using a ball-wedge-bonder. Applying heat and pressure both devices are connected together. This thermocompression technique is sketched in fig. 6.

III. RESULTS

In a first step the n-doped substrate has to be polished to get a smooth surface with an excellent optical quality. In order to get an array of LED pixels the p-doped epitactical layer has to be etched down to the pn-junction. The necessary depth is approximately 9 µm for the GaAsP system. During the last processing step ohmic contacts are applied to the semiconductor using metal evaporation.

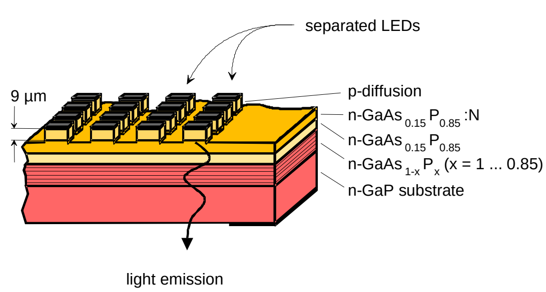


Fig. 5. GaAsP/GaP LED structure.

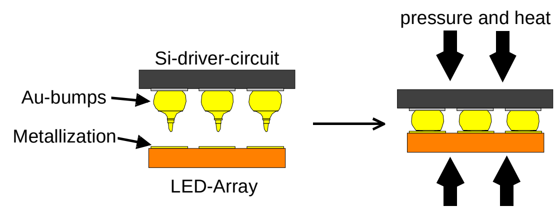


Fig. 6. Flip-chip-bonding based on thermocompression technique.

A. Etching

To realize single LEDs the wet chemical etchant for p-doped GaAsP has to comply with the following properties:

- No narrowing and broadening of the LED edges.
- High etching rate concerning a depth of 9 µm.
- No deterioration of the optical and electrical properties.

Standard etching substances for GaAs-systems are H_2SO_4 and H_2O_2. Due to the experience in etching GaAsP systems the first step was using an acid containing this starting matter [8]. Assuming the mentioned condition the averaged etching rate of H_2SO_4:H_2O_2:H_2O=1:1:1 at room temperature is 50 nm per minute. For encreasing the etching rate HNO_3:HCL:H_2O = 3:1:1 at room temperature is used leding to an averaged rate of 300 nm per minute. In order to get the required depth of 9 µm the contact pads are covered with 2 µm positive photo resist. The samples are etched for 30 seconds. To avoid critical undercut the spin-coating and lithography procedure is repeated until the demanded depth is reached. Fig. 7 shows a section of a pixel array with isolated LEDs on the p-doped GaAsP wafer with 9 µm deep etched pads having a center distance of 200 µm.

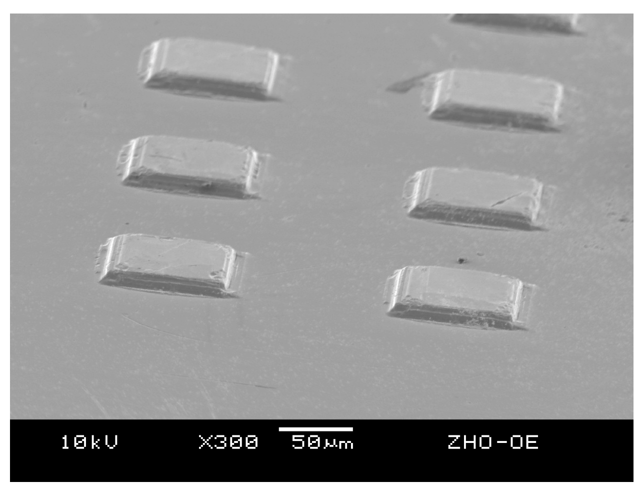


Fig. 7. SEM image of an LED array with 90 µm x 90 µm, each 9µm in high and 200 µm in distance.

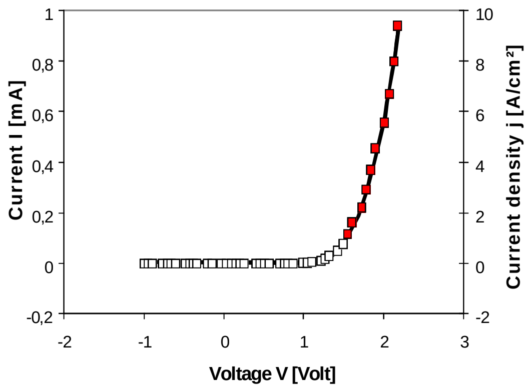


Fig. 8. I-V curve of a single LED pixel.

B. Metallization

For the p-doped site the following layers are used: Pd(45nm)/Ge(90nm)/Ti(30nm)/Pt(50nm)/Au(100nm). The n-doped substrate site is evaporated with Ge(30nm)/Pt(10nm)/Au(100nm). Finally the contacts are alloyed at a temperature of 450°C for 60 seconds. As a result fig. 8 shows the I-V curve for one pixel of the array with the start of light emission at approx. 100 µA.

C. Device integration

Fig. 9 shows gold-bumps bonded to the Si-driver circuit using a standard ball-wedge bonder. The size of the contact pads is 100 µm x 100 µm with a 200 µm pitch. The LED array is connected to the Si-driver circuit by using flip-chip-bonding techniques. Some important parameters among others are:

- Pressure: 20 cN
- Temperature: 320°C for the LED chip, 340°C for the Si-driver circuit.

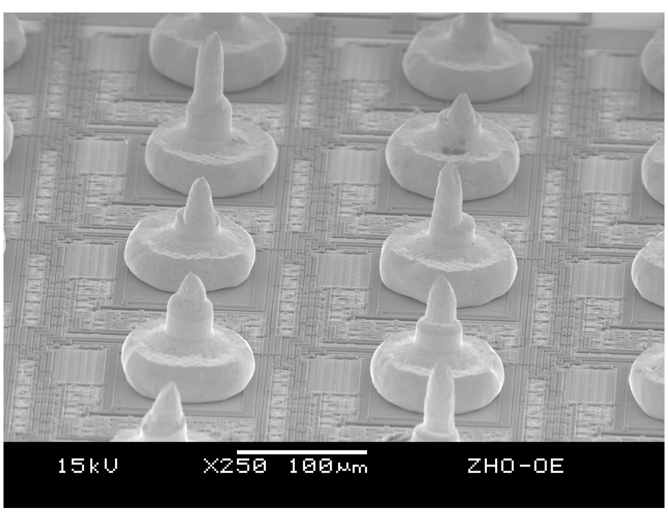


Fig. 9. Gold bumps bonded on a Si-driver-circuit.

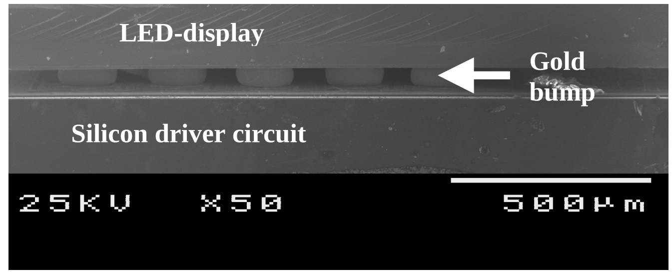


Fig. 10. SEM image of a Flip-chip-bonded LED array on a Si-driver-circuit.

The result of such a bonding process is shown in fig. 10. In fig. 11 the realized prototype of a 8x8 micro display with a total area of only 3.2 mm² bonded into a DIL casing is depicted.

IV. Conclusion

In this paper a prototype of a miniaturised LED display applied to an implantable intraocular microsystem is presented. The connection to a silicon driver circuit is demonstrated using flip-chip technology. The LED display can be considered as the first step on the way to a LED array with much higher resolution. Therefore other bumping processes like electroplating or anisotropic conductive adhesives or films will be used for future flip-chip procedures.

Acknowledgment

This work is financially supported by the Deutsche Forschungsgemeinschaft (DFG). The authors wish to thank all partners of the IOVA consortium for their contribution to this work. Finally, we thank Vishay-Telefunken in Heilbronn for making the GaAsP/GaP wafer available to us.

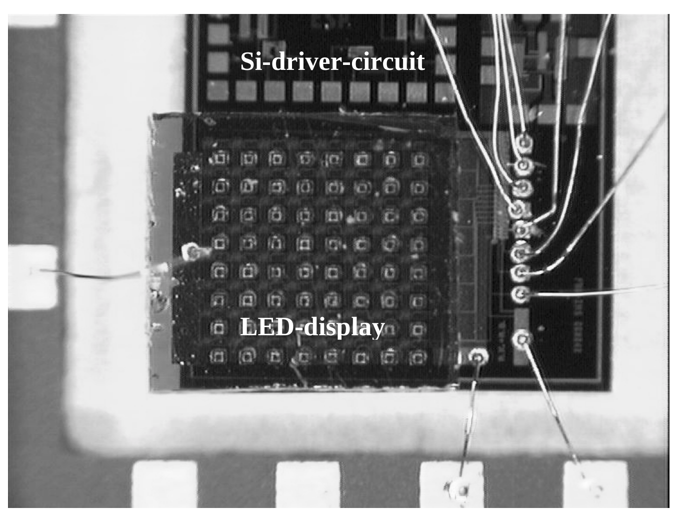


Fig. 11. Flip-chip-bonded device in a DIL casing.

REFERENCES

[1] P. Walter, U. Bartz-Schmidt, "Perspectives of Intraocular Microsystems – Retina Implants, Pressure Sensors, and Intraocular Vision Aids," *Proceedings of the World Microtechnologies Congress MICRO.tec 2000,* Hannover, pp. 433-436, 2000.

[2] W. Stork, K. D. Müller-Glaser, "Microdisplays as Intraocular Vision Aid – Optical and Physiological Constrains," *Proceedings of the World Microtechnologies Congress MICRO.tec 2000,* Hannover, pp. 449-452, 2000.

[3] F. Prämaßing, D. Püttjer, R. Buß and D. Jäger, "Intraocular Vision Aid (IOS): Optical Signal Transmission And Image Generation," *World Congress on Medical Physics and Biomedical Engeneering*, Chicago, 2000.

[4] R. Buß, F. Prämaßing, D. Püttjer and D. Jäger, "Optical Signal and Energy Transmission for Implantable Intraocular Microsytems," *Proceedings of the World Microtechnologies Congress MICRO.tec 2000,* Hannover, pp. 461-465, 2000.

[5] M. Schwarz, N. Hijazi, B. J. Hosticka, „CMOS Circuits for a Micro Implantable Intraocular Vision Aid," *Proceedings of the World Microtechnologies Congress MICRO.tec 2000,* Hannover, pp. 457-459, 2000.

[6] R.A. Logan, H.G. White and W. Wiemann, "Efficient Green Electroluminescent Junctions in GaP," *Solid State Electronics*, , vol. 14, pp. 55-70, 1971.

[7] R. Hall, "Recent Advances in GaAsP Technology", *Microelectronics*, Vol. 7, No. 3, pp. 13-18, 1976.

[8] J. Hong, S. J. Pearton, W.S. Hobson and H. Han, "Selective and Non-selective Wet Chemical Etching of $GaAs_{0.93}P_{0.07}$", *Solid State Electronics*, Vol. 39, No. 11, pp. 1675-1677, 1996.